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BRANCHINECTA SANDIEGONENSIS, A NEW SPECIES OF FAIRY SHRIMP (CRUSTACEA: ANOSTRACA) FROM WESTERN NORTH AMERICA

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Abstract.—*Branchinecta sandiegonensis,* a new species of fairy shrimp is described from vernal pools on Del Mar Mesa, San Diego County, California. The species is found within 50 km of the Pacific Ocean from Santa Barbara, California to Valle de las Palmas, Baja California Norte, Mexico. It can be distinguished from the other six branchinectids inhabiting southern California by the combination of thoracic spine pattern, ovary length, ovisac length and shape, and egg morphology of females and the form of the second antenna of males.

Vernal pools, so named for their colorful, springtime floral displays as the pools dry after winter rains, have long been known for their endemic floras (Crampton 1976, Holland & Jain 1977). Only one fairy shrimp however was known to be endemic to the extensive vernal pool habitat ranging from southern Oregon through the Central Valley of California and into northern Baja California, Mexico (Dodds 1923, Brtek 1964) before a recent monograph on the Anostraca of California described four endemic, vernal pool species (Eng et al. 1990). Here I describe another species found primarily in vernal pools atop mesas in San Diego County, California.

Methods

Animals were obtained either from filled pools or by hydrating soil samples from dry pools. Freshly molted individuals were fixed for 3 hours in 3% glutaraldehyde in 0.1 M sodium cacodylate at pH 7.4, post-fixed with 2% osmium tetroxide in sodium cacodylate for 2 hours, dehydrated in a graded series of 10% glacial acetic acid in absolute ethanol, and transferred to absolute ethanol. The eggs were air-dried from absolute ethanol, the mandibles were air-dried after 10 minutes in tetramethylsilane (Dey et al. 1989), and all other parts were critically point-dried, coated with gold-palladium and observed on a Philips 515 scanning electron microscope.

Branchinecta sandiegonensis, new species Figs. 1–13

Type material.—One ♂, holotype, USNM 256557, 1 ♀, allotype, USNM 256558, 2 ♂, 3 ♀, paratypes, USNM 256556, 3 ♂, 5 ♀, paratypes, Los Angeles County Museum of Natural History (LACM), LACM 90-356.1, 2 ♂, 3 ♀, paratypes, Hungarian Museum of Natural History, Del Mar Mesa, San Diego County, California, USA (32°51′N, 117°15′W), 17 Mar 1990 (coll. M. Simovich & M. Fugate); 4 ♂, 8 ♀, paratypes, LACM 89-357.1, 4 ♂, 5 ♀, paratypes Museo Ciencias Naturales de La Plata, Kearney Mesa (Miramar Naval Air Station), San Diego County, California (32°50′N, 117°09′W), 8 Feb 1990 (coll. M. Simovich); 50 ♂, 50 ♀, paratypes, USNM 294523, Ramona, San Diego County, California (33°02′N, 116°52′W), 4 Mar 1962 (coll. J. E. Lynch); 50 ♂, 50 ♀, para-

types, USNM 305974, Poway, San Diego County, California (32°55′N, 117°04′W), 3 Mar 1962 (coll. J. E. Lynch).

Type locality.—An extensive network of vernal pools surrounded by chaparral on Del Mar Mesa, San Diego County, California, USA, 32°51′N, 117°15′W, elev. 100 meters, south and east of junction of Interstate 5 and Carmel Valley Road (Greenwood 1984).

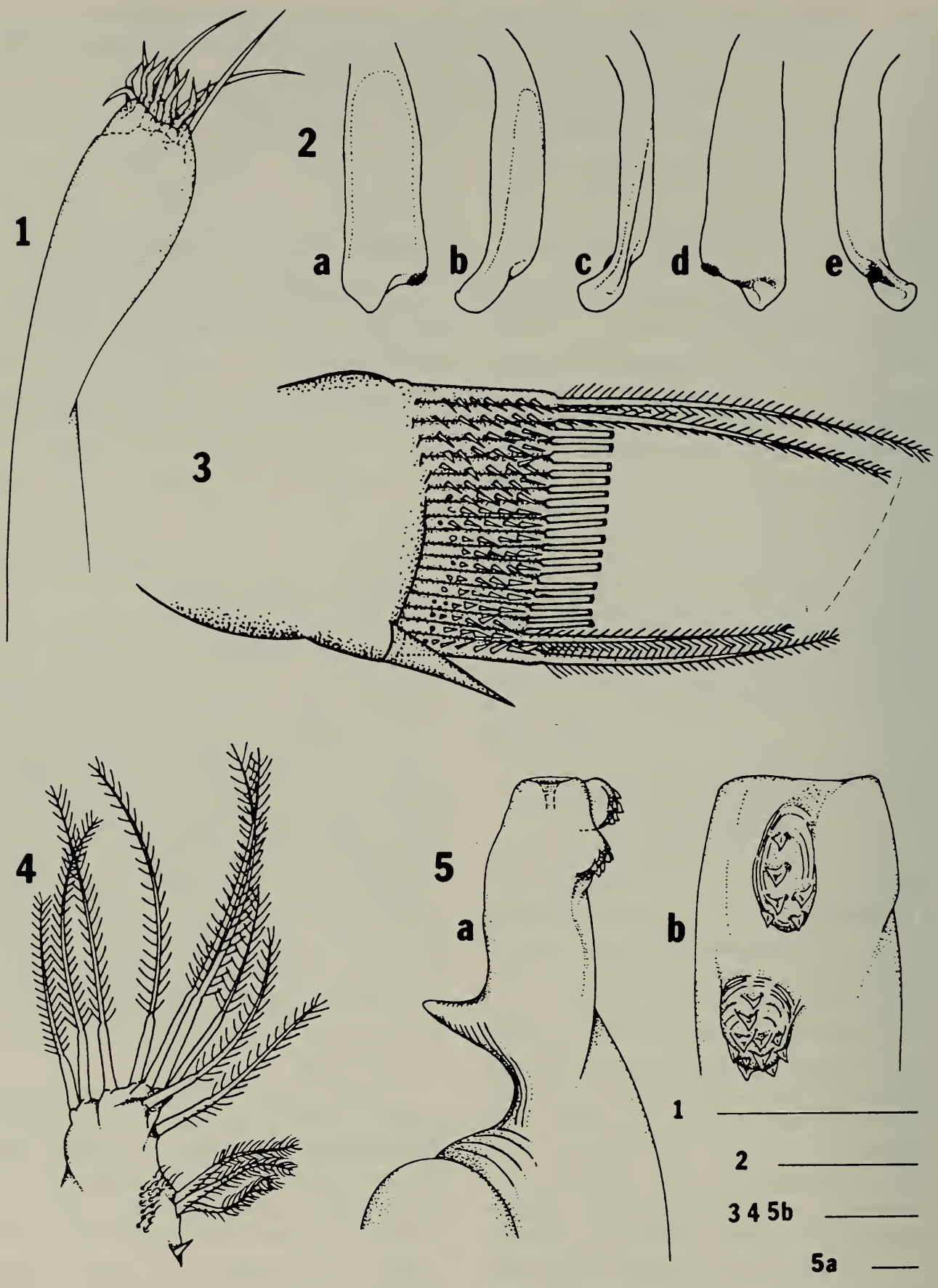
Etymology.—Named for San Diego County, California, USA.

Male.—Antenna 1 slender, cylindrical, approximately 10 times as long as wide, with 3 long setae and 8 or more shorter aesthetascs (type 1 and type 2 sensilla, respectively—Tyson & Sullivan 1979; Fig. 1). Antenna 2 biarticulate, cylindrical, reaching to thoracic segment 8 (Fig. 6). Basal and distal segments of approximately equal length. Basal segment with medial, oval pulvillus, near proximal end, of short spines interspersed with slightly longer, stouter, conical spines (Fig. 10a), medial, elevated cluster of 6–10 short, stout spines, half distance from end of basal segment (Fig. 6a), and single row containing clusters of papillae, each with sensory seta, on distal 0.67 of anterolateral surface. Distal segment slightly arcuate, upper 0.25 cylindrical, remainder mediolaterally flattened (Fig. 2a–e). Breadth 0.2 length at joint with basal segment expanding to 0.33 at tip. Mediolateral surfaces 6 times as broad as anteroposterior surfaces. Medial surface flat and lateral concave. Anterior 0.5 of distal portion inflated, turned in medially at 45°, ovoid anteriorly, triangular laterally. Posterior edge of distal portion with patch of raised, ovoid papillae arranged in rows (Fig. 10b).

Body of mandible with spinelike protuberance on posterolateral surface. Molar surfaces of mandibles asymmetrical, broadly oval with dorsal edge concave and ventral convex, divided into 2 basic regions, an anteroventral and posterodorsal (Tyson & Sullivan 1981, Fig. 11). Anteroventral region of both molar surfaces similar, with approximately 45 ridges and furrows, some bifurcating, running dorsoventrally. Ridges of rectangular cuticular projections bearing many conical protuberances, both projections and protuberances becoming taller near edges of molar surface. Ridges extend to dorsal edge on anterior half of right mandible, but only on anterior 0.15 of left. Posterodorsal region with 1 long, thin spine at posterior edge and row of spines, decreasing in size anteriorly, along dorsal edge. On right mandible, spines sickle-shaped, each bordering short row of widely spaced cuticular projections, and each row in turn bordering small area of relatively unadorned cuticle dorsal to ridges of anteroventral region. On left mandible, spines squat, conical, and more widely spaced, becoming longer and thinner anteriorly and bordering large area of unadorned cuticle extending almost entire length of molar surface.

Maxilla 1 with short, stout spine on ventral edge and 18 setae, approximately 3 times as long as ventral spine, on medial edge (Fig. 3). Proximal 0.33 of seta with 4–7 stout spinules, arranged in single row, along medial surface, distal 0.67 with 2 rows of setules. Maxilla 2 small, with 6–10 setae on crown (Fig. 4). Setae pliant, with 2 rows of setules on distal 0.8. Medial surface of maxilla 2 with 2–3 short, pliant setae covered with setules, not arranged in rows, and 1 small, stout spine nearer base. Ventral surface of labrum broadly triangular with lateral flap on each side, posterior edge of flaps spinose. Oral surface with small, distal lobe covered with fine setae.

Thoracic segments appendage-bearing, with paired dorsolateral, cuticular papillae, each papillus with sensory seta (Figs. 6, 9). Papillae not on raised protuberances, lateral on segments 1–3, 5–8, and 10–11, dorsal on 4 and 9 (compare Lynch 1960, fig. 4 and Cohen 1983, fig. 22). All 11 pairs of appendages similar in form, but those of segment 11 reduced (Fig. 8). There is much confusion as to which lobes of anostracan phyllopodous limbs are homologous with



Figs. 1–5. *Branchinecta sandiegonensis,* new species male. 1. antenna, 1, distal tip. 2a–e. antenna 2, distal segment. a. lateral. b. anterolateral. c. anterior. d. medial. e. dorsomedial. 3. maxilla 1, medial view. 4. maxilla 2, posterior view. 5a, b. right penis. a. ventral view. b. distal tip, lateral view. (scale bars 2, 4, 5, 6: 0.1 mm, 3: 1 mm)

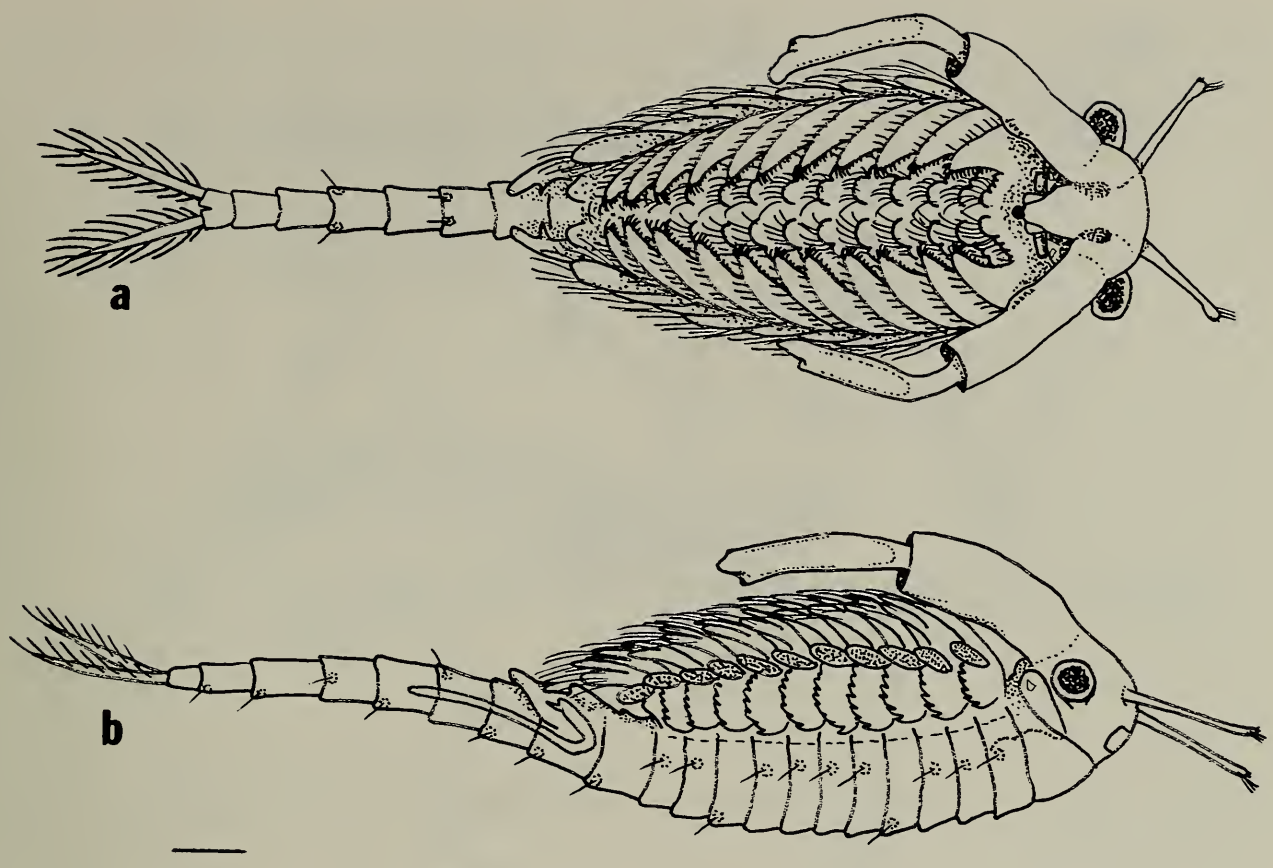
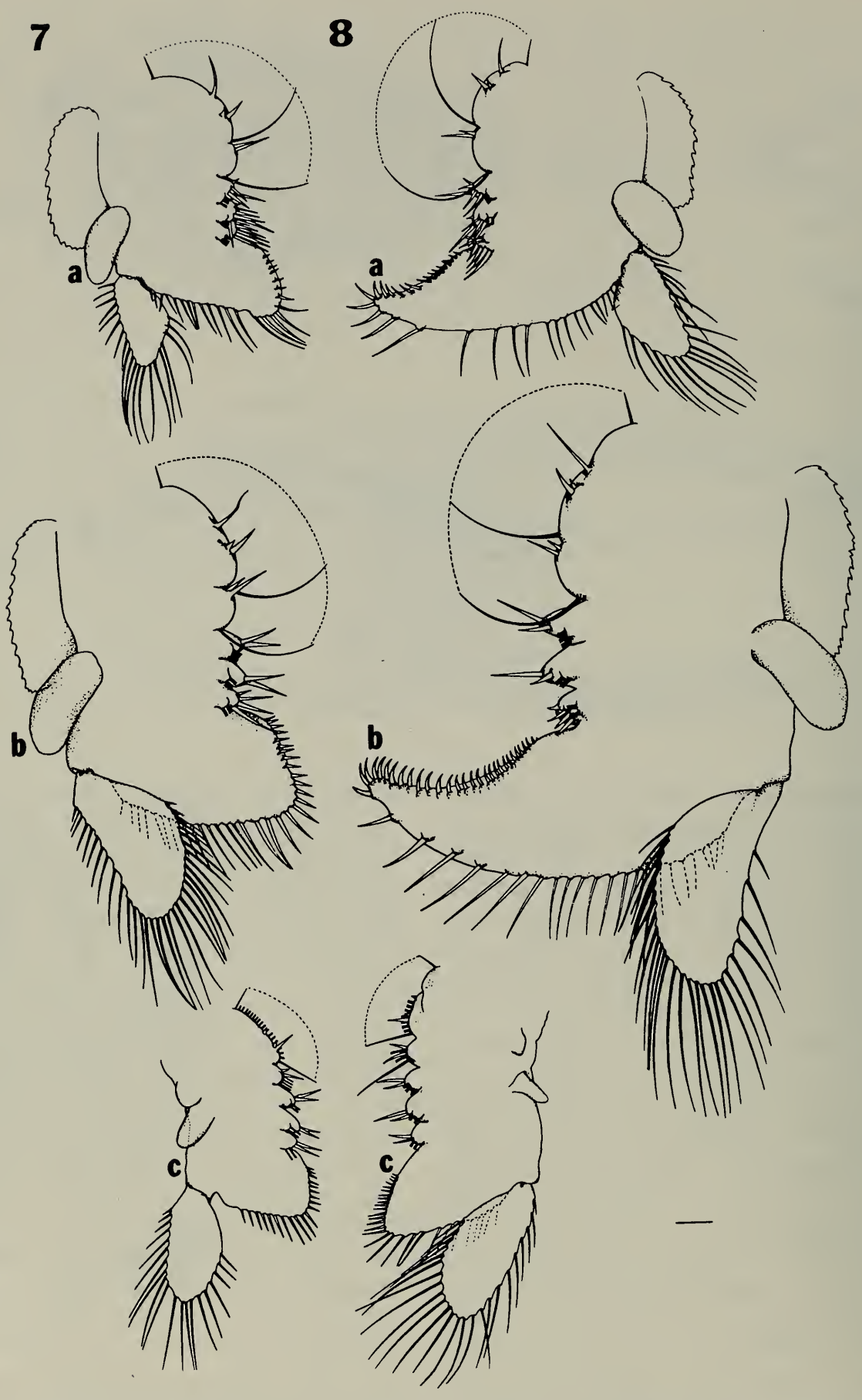


Fig. 6. *Branchinecta sandiegonensis,* new species male. a. ventral view. b. lateral view. (scale bar 1.0 mm)

stenopodous limbs. Here the nomenclature of Linder (1941) is employed. Endite 1 with 3 centers of origin for its numerous posterior setae. Middle series with 7–9 posterior setae and long, slightly toothed anterior seta. Distal series with 11–16 posterior setae and 2 anterior setae on basal edge, distal seta comblike, with single row of stout setules, basal seta shorter, spiniform. Appendage 11 with 3–5 posterior setae and short, spiniform anterior seta in middle series and 4–6 posterior setae in distal series (Fig. 8c). Endite 2 similar to distal series of endite 1, with 13–18 posterior setae and 2 anterior setae. Appendage 11 with posterior setae reduced to 2–4. Endites 3, 4, and 5 with 3, 2, and 2 posterior setae, respectively (Figs. 8 & 12a). Endites 3 and 4 with 2 anterior setae on appendages 2–11 and 4–7 anterior setae on appendage 1. Endite 5 with 2–6 anterior setae on appendages 2–11 and 4–8 on appendage 1. Endopodite large, elongate, shaped like broad scimitar (Fig. 8). Setae along medial edge with several rows of fine setules surrounding distal 0.67 (Fig. 12b), becoming comblike toward ventral edge, along ventral edge, long and thin, with 2 rows of fine setules. Exopodite oval to triangular, surrounded by setae resembling those of ventral edge of endopodite. Epipodite smooth, inflated, without setae. Preepipodite thin, semicircular, with coarsely toothed edge, reduced on appendage 11. Early in development with 2 lobes, in adults with slight notch along lateral edge.

Genital segments only slightly expanded, paired papillae dorsal, paired penes arising ventrolaterally. Non-rectractile portion of penis with ventral, fleshy lobe and medially-directed, sclerotized spur (Fig. 5a). Distal portion of penis eversible with two small, sclerotized lobes on lateral surface each with six to ten pyramidal teeth (Fig. 5b).

Post-genital segments with paired papillae in following positions: one, dorsal, two, ventral, three, dorsal, four, lateral, five and



Figs. 7–8. *Branchinecta sandiegonensis,* new species, 7a–c. thoracic appendages female. a. appendage 1. b. appendage 5. c. appendage 11. 8a–c. thoracic appendages male. a. appendage 1. b. appendage 5. c. appendage 11. (scale bar 0.1 mm)

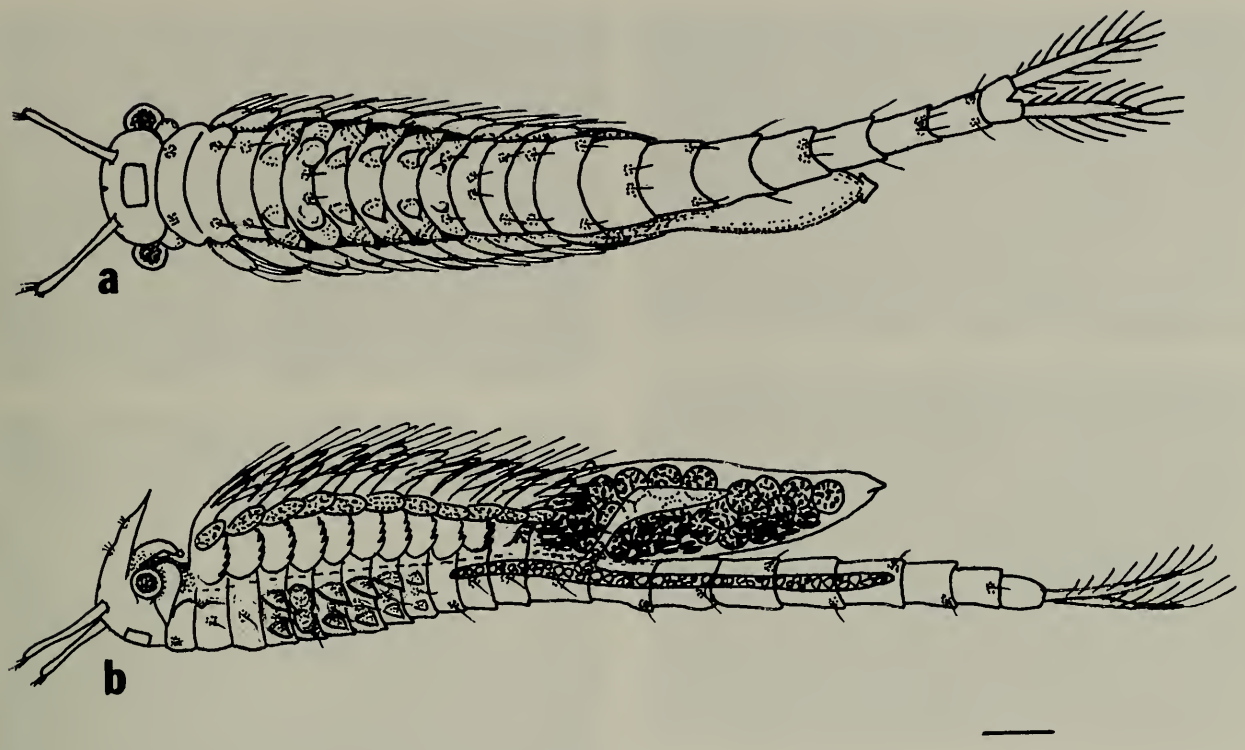


Fig. 9. *Branchinecta sandiegonensis,* new species female, a. dorsal view. b. lateral view. (scale bar 1.0 mm)

six, dorsal. Cercopods on anal segment bearing setae with 2 rows of fine setules (Cohen 1983).

Length of mature individuals, from front of head to end of anal segment, excluding cercopods, 9.0–16.0 mm.

Female.—Head similar to that of male, except for pair of cuticular papillae on dorsal surface, posterior to mandibular crease, and form of antenna 2 (Fig. 9). Antenna 2 cylindrical, approximately 3 times as long as wide basally, gradually tapering to 5 times as long as wide at 0.8 its total length, then rapidly to sharp point (Fig. 9b). Anterior surface with 2 patches of sensory setae, each seta borne on a cuticular papillus.

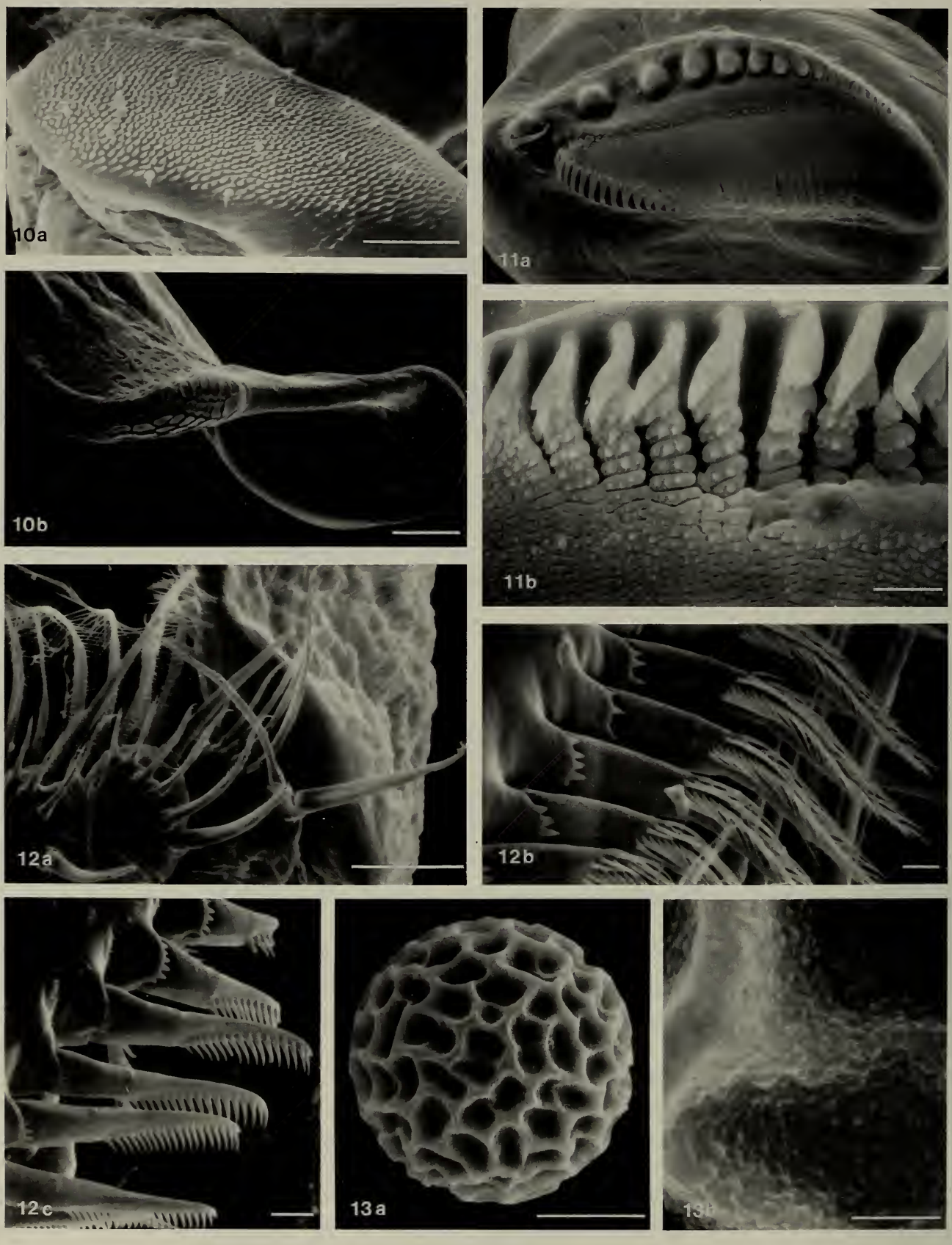
Thorax with cuticular papillae in same locations as male, but segments 3 and 5–8 with 2 pairs of dorsolateral spines arranged above and below papillus, dorsal normally smaller than lateral spines, segment 4 with 1 pair of large bilobed spines (Fig. 9). Thoracic appendages similar to male, but endopodite lobelike (Fig. 7a–c) with stout, comblike setae along entire medial edge (Fig. 12c).

Genital segments slightly inflated, with paired papillae lateral on segment 1 and dorsal on 2 (Fig. 9a). Ovisac fusiform, on average ending under post-genital segment 4, occasionally under segment 5. Paired ovaries t-shaped, extending from thoracic segment 9 or 10 to post-genital segment 4, and into ovisac at junction of two genital segments, forming an oviductal pouch. Resting eggs spherical, diameter $\tilde{X}$ = 269 μm, SD = 18 μm, range = 227–309 μm, n = 100, with numerous shallow hemispherical depressions, approximately 40 μm in diameter, covering surface (Fig. 13a, b).

Post-genital segments similar to male, but arrangement of papillae as follows: one, lateral, two, ventral, three, dorsal, four, ventral, five, dorsal, six, lateral.

Length of mature individuals, from front of head to end of anal segment, excluding cercopods, 8.0–15.0 mm.

Remarks.—The form of the male second antenna has served as the cardinal character for species identification in the genus and although all males are currently distinguishable on that basis, the use of that character



Figs. 10–13. *Branchinecta sandiegonensis,* new species, 10a, b. antenna 2 male. a. pulvillus on basal segment. b. tip of distal segment, dorsolateral view. 11a, b. mandibles male. a. left mandible, molar surface. b. right mandible, transition between posterodorsal and anteroventral regions. 12a–c. setae on medial surfaces of thoracic appendages. a. appendage 1 male, endites 3–5. b, c. medial edge of endopodite. a. male. b. female. 13a, b. resting egg. a. whole egg. b. surface detail. (scale bars, 1a, b, 3a, 4a: 0.1 mm, 2a, b, 3b, c, 4b: 0.01 mm)

alone can often lead to difficulties. *Branchinecta sandiegonensis* has been reported as *Branchinecta lindahli* Packard, 1883, a common species throughout western North America, by Ebert & Balko (1987) in a study of the vernal pools on Kearney Mesa, San Diego County, California (D. Belk, pers. comm.; vouchers in personal collection of D. Belk) and by Dr. J. E. Lynch in two earlier collections from San Diego County (USNM 305974, 3 Mar 1962, Poway, 32°55′N, 117°04′W; USNM 294523, 4 Mar 1962, Ramona, 33°02′N, 116°52′W). Five additional species in the genus are also known from southern California, but of those only *Branchinecta lynchi* Eng et al., 1990 is likely to be confused with *B. sandiegonensis*. *Branchinecta mackini* Dexter, 1956 and *Branchinecta gigas* Lynch, 1937 are found in large playa lakes in the Mojave, while *Branchinecta conservatio* Eng et al., 1990 and *Branchinecta longiantenna* Eng et al., 1990, although found in vernal pools, are readily distinguished morphologically. In general form, *B. sandiegonensis* females resemble those of *B. lindahli* due to the fusiform shape of the ovisac, however that of *B. lindahli* is slightly longer, typically ending under post-genital segment 5. *Branchinecta lindahli* differs also in having a longer ovary, extending from thoracic segment 4–7 to post-genital segment 4, an egg with hemispherical surface depressions, approximately 20 μm in diameter, and a single dorsolateral spine, always below the papillus, on each side of thoracic segments 3–11. *Branchinecta lynchi* females share a similar ovary length, egg surface (Mura 1991), and dorsolateral spine pattern with *B. sandiegonensis,* but differ in having a short, conical ovisac, typically ending under post-genital segment 3.

Males of *B. sandiegonensis* share the large, oval pulvillus on the basal segment of the second antenna with *B. lindahli,* but the medial series of spines is less diffuse. The distal segment is broadest in *B. sandiegonensis* just proximal to the tip, while that of *B. lindahli* is at 0.75 the distance from base. The breadth at the tip in *B. lindahli* is only slightly larger than at the joint with the basal segment and the entire tip is bent medially at a right angle to the segment of the antenna just preceding it (Shantz 1905, Lynch 1964). The second antenna of *B. lynchi* is quite different; the pulvillus is smaller, there is a small apophysis, slightly distal and posterior to the pulvillus, the distal segment has a narrower breadth, and the entire tip is bent medially (Eng et al. 1990).

Distribution and habitat—Branchinecta sandiegonensis is found after winter rains in vernal pools from northern Baja California Norte, Mexico (Valle de las Palmas, Baja California Norte, Mexico 32°28′N, 116°37′W, 15 Nov 1987, soil sample, coll. M. Fugate & G. Pratt) to Santa Barbara, California (Isla Vista, Santa Barbara County, California 34°24′N, 119°51′W, 1, 7 Apr 1991, coll. J. Kornmeyer). Its current range is centered in San Diego County, California (Del Mar Mesa, Kearney Mesa, Ramona, Otay Mesa, 32°34′N, 116°58′W). All known localities are within 50 km of the Pacific Ocean and at elevations less than 700 m. There are no records from Los Angeles and Orange counties and it is unknown if the Santa Barbara population is either disjunct or the northern end of a formally continuous distribution.

The pools in San Diego County are shallow (<30 cm) and often on chaparral covered mesas (Greenwood 1984, Ebert & Balko 1987). Zedler (1984) found 46 plant species common in pools at Kearney Mesa, one of which is endangered (*Pogogyne abramsii*) and Ebert & Balko (1987) found *B. sandiegonensis* associated with six cladocerans, one copepod, nine ostracods and at least 21 rotifer species at the same site. *Streptocephalus woottoni* Eng et al., 1990 and *B. lindahli* have subsequently been found at Kearney Mesa, the former in a pool containing *B. sandiegonensis* and the latter in a road rut, but not in pools containing *B. sandiegonensis* (M. Simovich, pers. comm.).

Branchinecta sandiegonensis has been found in a disturbed pool with *B. lindahli* at Del Mar Mesa and in two pools with *S. woottoni* and a clam shrimp, *Cyzicus* sp. at Otay Mesa.

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Literature Cited

Brtek, J. 1964. Ein neue Gattung und Familie der Ordnung Anostraca.—Annotationes Zoologicae et Botanicae (Bratislava) 7:1–7.

Cohen, R. G. 1983. Notas sobre anostracos neotropicales (Crustacea). III. *Branchinecta somuncurensis* y *Branchinecta prima* spp. nov.—Physis (Buenos Aires) 41B:69–80.

Crampton, B. 1976. A historical perspective on the botany of the vernal pools in California. Pp. 5–10 *in* S. Jain, ed., Vernal pools: their ecology and conservation. Institute of Ecology Publication No. 9, University of California, Davis, 93 pp.

Dey, S., T. S. Basu Baul, B. Roy, & D. Dey. 1989. A new rapid method of air-drying for scanning electron microscopy using tetramethylsilane.—Journal of Microscopy 156:259–261.

Dodds, G. S. 1923. A new species of a phyllopod.—Occasional Papers of the Museum of Zoology, University of Michigan 141:1–3.

Ebert, T. A., & M. L. Balko. 1987. Temporary pools as islands in space and time: the biota of vernal pools in San Diego, southern California, USA.—Archiv fur Hydrobiologie 110:101–123.

Eng, L. L., D. Belk, & C. H. Eriksen. 1990. Californian Anostraca: distribution, habitat, and status.—Journal of Crustacean Biology 10:247–277.

Greenwood, N. 1984. The physical environment of series H, vernal pools in San Diego County, California. Pp. 30–36 *in* S. Jain & P. Moyle, eds., Vernal pools and intermittent streams. Institute of Ecology Publication No. 28, University of California, Davis, 280 pp.

Holland, R. F., & S. K. Jain. 1977. Vernal pools. Pp. 515–533 *in* M. Barbour & J. Major, eds., Terrestrial vegetation of California. John Wiley & Sons, New York, 1002 pp.

Linder, F. 1941. Contributions to the morphology and the taxonomy of the Branchiopoda Anostraca.—Zoologiska Bidrag fran Uppsala 20:101–302 + 1 plate.

Lynch, J. E. 1960. The fairy shrimp Branchinecta campestris from northwestern United States (Crustacea: Phyllopoda).—Proceedings of the United States National Museum 112:549–561.

———. 1964. Parkard's and Pearse's species of *Branchinecta*: analysis of nomenclatural involvement.—American Midland Naturalist 71:466–488.

Mura, G. 1991. SEM morphology of resting eggs in the species of the genus *Branchinecta* from North America.—Journal of Crustacean Biology 11: 432–436.

Shantz, H. L. 1905. Notes on North American species of Branchinecta and their habitats.—Biological Bulletin 9:249–263 + plates X–XII.

Tyson, G. E., & M. L. Sullivan. 1979. Antennular sensilla of the brine shrimp, *Artemia salina*.—Biological Bulletin 156:382–392.

———. 1981. A scanning electron microscopic study of the molar surface of the mandibles of the brine shrimp (Cl. Branchiopoda: Or. Anostraca).—Journal of Morphology 170:239–251.

Zedler, P. H. 1984. Micro-distribution of vernal pool plants at Kearney Mesa, San Diego County. Pp. 185–197 *in* S. Jain & P. Moyle, eds., Vernal pools and intermittent streams. Institute of Ecology Publication No. 28, University of California, Davis, 280 pp.

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